CALIFORNIA
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PIER RENEWABLE ENERGY TECHNOLOGIES PROGRAM

RESEARCH DEVELOPMENT AND DEMONSTRATION ROADMAP

STAFF REPORT

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Arnold Schwarzenegger, *Governor*

CALIFORNIA ENERGY COMMISSION

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ABSTRACT

This report is a roadmap for the Public Interest Energy Research program in renewable energy at the California Energy Commission. The objective of this roadmap is to identify key areas of focus (called milestones) for future research, development, and demonstration for PIER Renewable group that will help achieve the state renewable energy policy goals. The vision for the roadmap is to provide at least 33 percent of the electricity in the California energy system by 2020, providing consumers and energy providers with affordable, reliable, secure, and diverse clean energy services.

The roadmap was developed through extensive input from both internal and external stakeholders. It includes the following state renewable energy policy goals: the Renewable Portfolio Standard, the California Solar Initiative, and the Bioenergy Action Plan for California. In addition, the greenhouse gas reduction targets specified by Governor Schwarzenegger were considered to be an important element for renewable energy policies in future.

The roadmap includes the following renewable energy resources and technologies: shared renewables, utility scale wind, geothermal, biopower, biofuels, solar photovoltaic, concentrated solar power, small hydro, ocean/wave/tidal, distributed generation wind, and natural gas displacement with renewable energy. PIER Renewable Group will use the detailed roadmaps to prioritize where PIER investments will produce maximum benefit for the state.

The Roadmap consists of five key elements: policy goals, vision, platforms, strategic objective, and milestones. Four platforms, each with strategic objectives, were defined to organize the research activities. These are: production resources and technology, grid integration, end use, and market transformation. production technology will support commercialization of renewable technologies, grid integration will enable integrating the renewable energy resources into the California electricity grid, end use will support adoption of renewable energy by end users, and market transformation will support appropriate market mechanisms and policies that enable sustainable growth of renewable energy.

Key words: Roadmap, renewables, platform, milestones, production technology, grid integration, end use, market transformation, wind, geothermal, biopower, biofuels, solar photovoltaic, CSP, hydro.

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EXECUTIVE SUMMARY

In December 2005, the Energy Commission's Public Interest Energy Research (PIER) Program began an effort to develop a Renewable Energy research, development, and demonstration (RD&D) roadmap (Roadmap) to provide a planning mechanism and communication tool that establishes a clear link between the priorities of the Public Interest Energy Research program in renewable energy (PIER Renewables) and the key California state renewable energy policy goals.

The Roadmap relied on input from external stakeholders and other groups within PIER and the Energy Commission. The process included internal workshops for the PIER Renewables staff, meetings with other Energy Commission areas, and interviews and a one-day workshop with external stakeholders from government, utilities, industry companies, advocacy groups, and research organizations.

The Roadmap consists of five key elements: policy goals, vision, platforms, strategic objective, and milestones. Key state renewable energy policy goals identified include the Renewables Portfolio Standard goals of 20 percent by 2010 and 33 percent by 2020, the California Solar Initiative, and the Bioenergy Action Plan for California. In addition, PIER Renewables identified Governor Schwarzenegger's greenhouse gas reduction targets as a potentially important policy for renewables in the future.

The vision developed by PIER Renewables staff for the Roadmap is: "Renewable energy resources will provide at least 33 percent of the electricity by 2020 for the California energy system, providing consumers and energy providers with affordable, reliable, secure, and diverse clean energy services." While the Roadmap contains biofuels and natural gas issues, they are considered only in areas where they overlap with renewable energy as it pertains to electricity generation.

PIER Renewables defined four platforms to help organize and structure research activities and defined the strategic objectives for each platform. The production resources and technology platform will support commercialization of renewable energy options. The grid integration platform will enable renewable energy grid integration. The end-use platform will support end-user adoption of renewable energy. The market transformation platform will support appropriate market mechanisms and policies that enable sustainable renewable energy growth.

To define the research, development and demonstration milestones, PIER renewables staff developed detailed roadmaps for each energy resource/technology area. These areas are: Shared Renewable Issues, Utility Scale Wind, Geothermal, Biopower, Biofuels, Solar Photovoltaic, Concentrated Solar Power, Small Hydro, Ocean/Wave/Tidal, Distributed Generation Wind, and Natural Gas Displacement/Replacement. PIER Renewables will use the detailed roadmaps to prioritize where PIER investments will produce maximum benefit for the state.

CHAPTER 1: INTRODUCTION

Background

The Public Interest Energy Research Program (PIER), established in 1996 as part of Assembly Bill 1890 (Brulte), Chapter 854, Statutes of 1996, includes a requirement that at least $62.5 million be collected annually from investor-owned utility ratepayers for "public interest" energy research and development efforts that are not adequately provided by competitive and regulated markets.

PIER supports energy research, development and demonstration (RD&D) projects that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program annually awards up to $62 million to conduct the most promising public interest energy research by partnering with RD&D organizations including individuals, businesses, utilities, and public or private research institutions. PIER funding focuses on seven programmatic areas including renewable energy technologies.

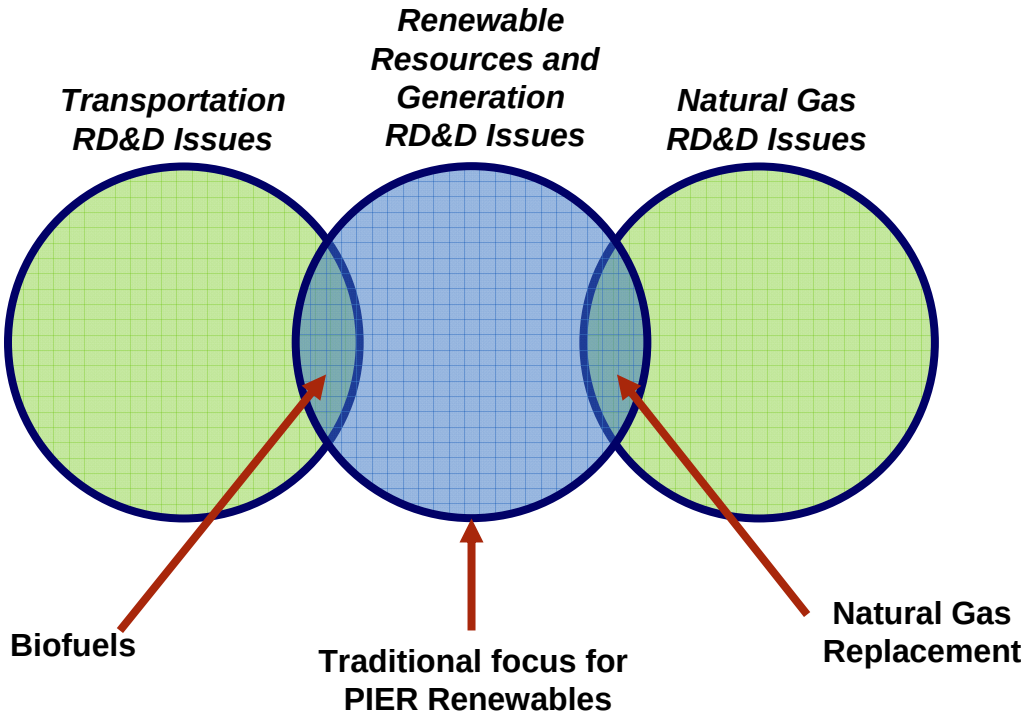
PIER's Renewable Energy Technologies Program (PIER Renewables) advances and accelerates market adoption of renewable energy technologies that are key to meeting state energy policy goals by:

- Advancing market adoption of renewable energy resources and generating technologies through innovation, performance improvements, and cost reduction, as well as advancing the production of transportation fuels with renewable resources.
- Enabling effective interconnection of renewable generation to the electrical transmission and distribution system.
- Encouraging end-user adoption of distributed renewables by addressing technology and market issues.
- Supporting development of appropriate market mechanisms and policies to enable sustainable renewable energy growth.

Traditionally, PIER Renewables has focused on RD&D activities in renewable energy resources and technologies for electricity generation. With PIER's recent addition of the natural gas and transportation RD&D focus, PIER Renewables is now expanding RD&D considerations and investments into areas that clearly overlap these areas. Figure 1 shows the PIER Renewables primary focus area and overlaps with natural gas and transportation, which include:

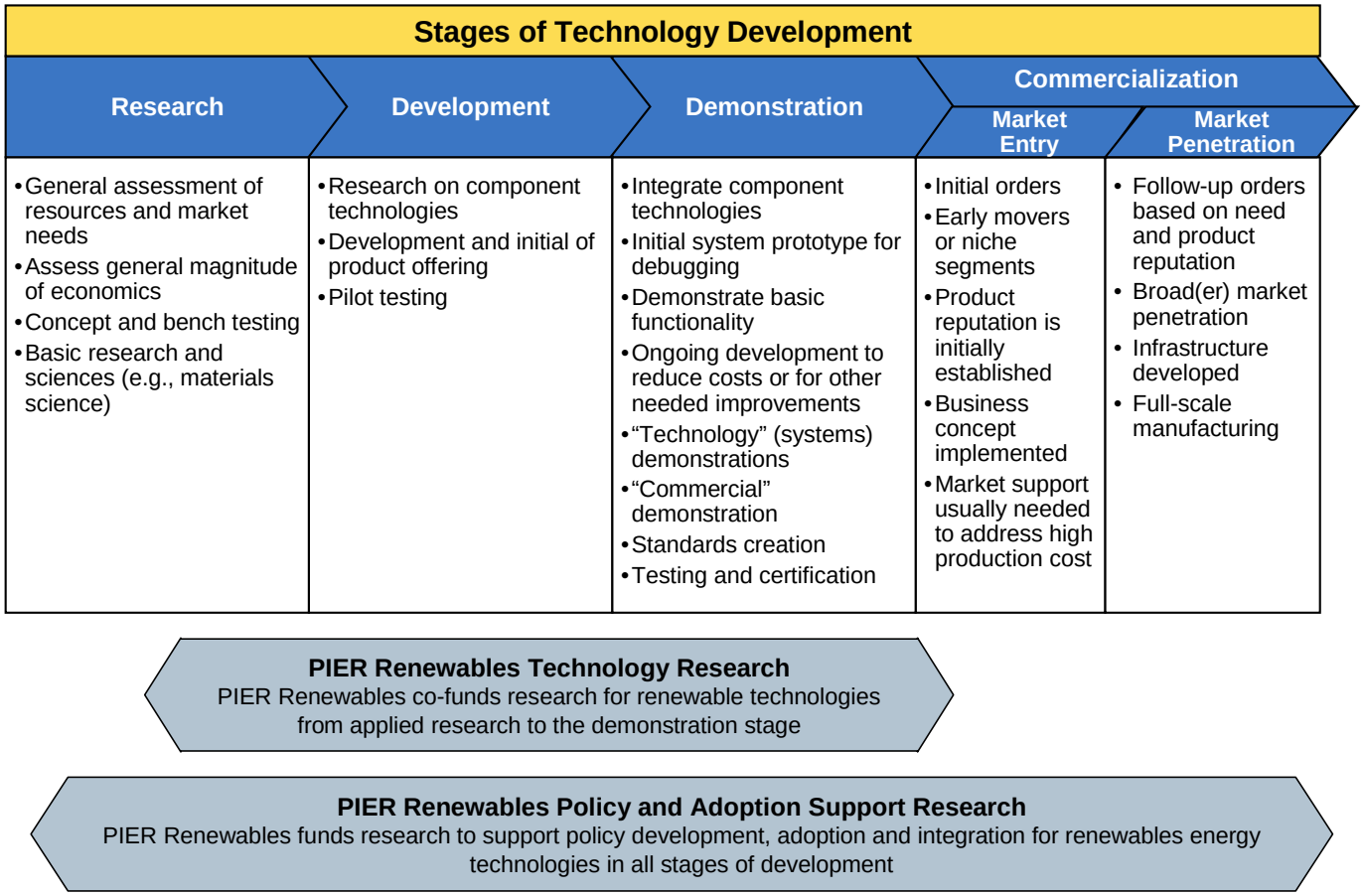
1. Transportation issues as they pertain to biofuels production.
2. Natural gas issues as they pertain to replacing natural gas use with renewable energy applications.

Figure 1: PIER Renewables Areas of Focus



Funding for renewables RD&D focuses on applied research through design, development and demonstration stages of technology development. In addition, PIER Renewables also funds research to help develop state energy policy and meet adopted energy goals. Figure 2 below describes the stages of technology development where PIER Renewables focuses its funding.

Figure 2: Stages of Technology Development and PIER Renewables Role



From July 1, 2000 through June 30, 2005, PIER Renewables invested $53.6 million in renewables RD&D activities. PIER's 2005 annual report describes the RD&D projects funded by PIER Renewables and is available on the California Energy Commission website.[1]

RD&D Roadmap Rationale

The challenge for PIER Renewables is determining how to invest limited RD&D dollars to help the state achieve aggressive renewable energy policy goals. Part of the challenge stems from the lack of clear directive for RD&D priorities between the renewable resources and technologies. For example, California's RPS does not specify the mix of technologies to be used.

To support state policy goals, PIER Renewables will need to:

- Make investment decisions based on broad policy direction.
- Incorporate flexibility into its planning since renewable energy policy and technologies will evolve over time.
- Identify partnership opportunities to leverage funding from other states, the federal government, universities, and private industry.

In December 2005, PIER Renewables began a project to develop a Renewable Energy RD&D Roadmap (Roadmap). The purpose for developing the Roadmap was to provide a planning mechanism and communication tool that clearly establishes a link between PIER Renewables RD&D priorities and key California state renewable energy policy goals.

The Roadmap identifies RD&D investments that will help the state meet ambitious renewable energy policy goals. In addition, PIER Renewables will use the Roadmap to prioritize the areas where investment by PIER will produce maximum benefit for the state. In addition, the Roadmap:

- Provides a clear framework for focusing RD&D efforts toward meeting state policy goals.
- Allows PIER Renewables to establish research priorities based on short-term and long-term goals.
- Communicates to stakeholders what PIER Renewables is focused on and intends to achieve.
- Contains different platforms to encompass a range of strategic RD&D areas.
- Is designed to be used as an updateable planning and management tool.
- Will evolve over time as policy, markets, and technologies evolve and priorities shift.

The number of RD&D activities identified through the road mapping effort far exceeds what PIER Renewables can accomplish alone. The intent was to capture key RD&D priorities needed to achieve policy targets (such as the 2010 RPS, the California Solar Initiative, state bioenergy goals).To meet the milestones in the Roadmap, several organizations must implement RD&D projects, including PIER Renewables, the private sector, the federal government, other state governments, and universities. PIER Renewables will use the RD&D milestones detailed in the Roadmap to establish research and investment priorities. This report documents the PIER road mapping effort.

RD&D Roadmap Approach

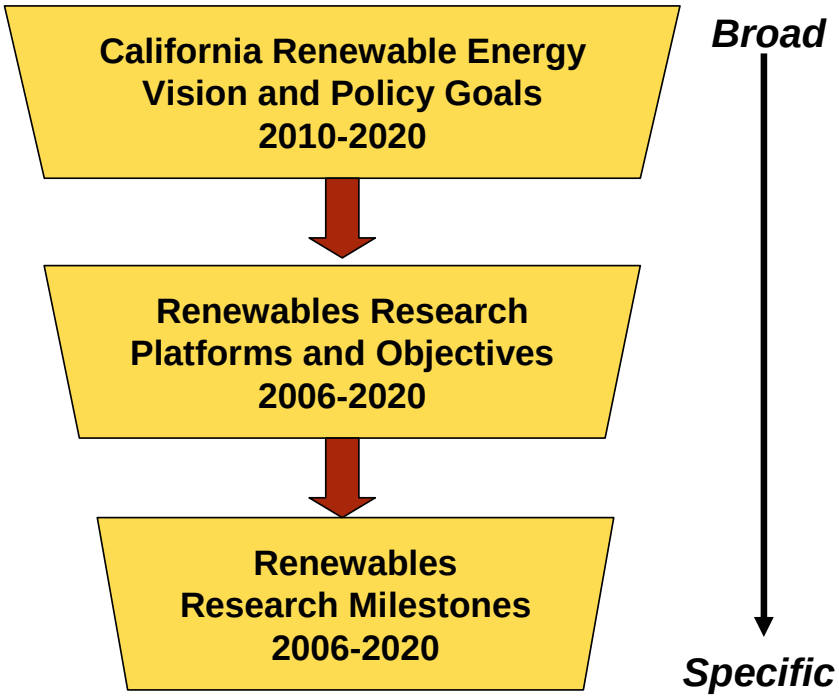
The Roadmap comprises five key elements: policy goals, vision, platforms, strategic objective, and milestones. Figure 3 describes each element and explains its importance for the Roadmap.

Figure 3: Key Elements of Roadmap

Roadmap Element	Definition	Why it is important
Policy Goals	The key renewable energy state policy goals	Establishes the policy goals that RD&D investments should support
Vision	Statement that briefly describes the end-point that the program is working toward	Provides an overall target to achieve
Platforms	Strategic areas of focus for investment and management attention that identify where PIER Renewables hopes to make an impact	Helps organize and structure the research activities
Strategic Objectives	The key goal PIER Renewables is working to accomplish for each Platform	Provides a point of focus for what is strategically important by Platform
Milestones	A series of specific goals with a target date that will lead to the accomplishment of the strategic objectives	Breaks down the strategic objectives into a series of “bite-size” goals

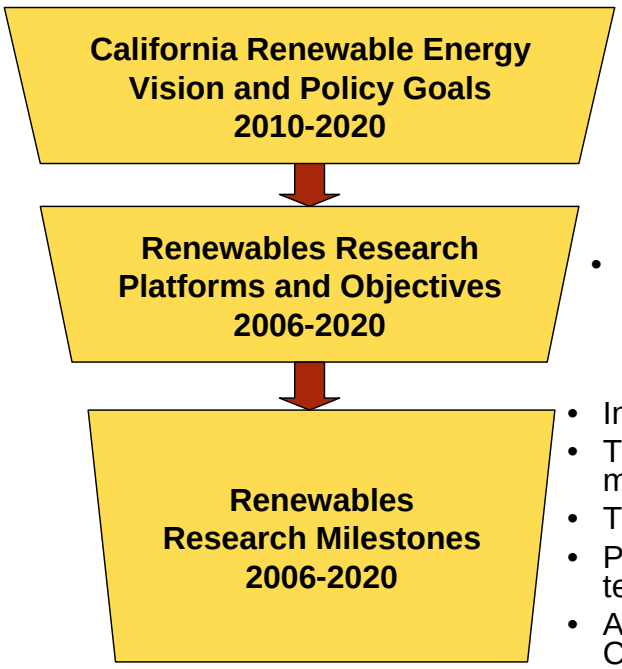
The Roadmap was developed between December 2005 and April 2006. Starting with the state vision and policy goals for renewable energy, a number of research platforms and objectives were defined. Then specific milestones were defined to help achieve the objectives, as illustrated in Figure 4.

Figure 4: Overview of Process Used to Develop Roadmap



The Roadmap relied on input from external stakeholders and other groups within PIER and the Energy Commission. The process included internal workshops for the PIER Renewables staff, meetings with other groups within the Commission, interviews with stakeholders and a one-day workshop with stakeholders. Figure 5 summarizes the specific activities used to develop the Roadmap. The Appendix contains a list of the stakeholders interviewed for input to the Roadmap and a list of participants in the one-day stakeholder workshop.

Figure 5: Details of Process Used to Develop Roadmap



Key activities

- Reviewed key renewables energy policy documents
- First internal PIER Renewables workshop
- Second internal PIER Renewables workshop
- Interviewed 20 key RD&D organizations and
- Ten key PIER stakeholder organizations for input on milestones*
- Third internal PIER Renewables workshop
- PIER Renewables area team leads held >15 small-team meetings to refine milestones
- All day workshop with >30 external and >20 internal Commission participants for additional input on milestones*

* Lists of interviewees and workshop participants are provided in the Appendix

Overview of Report

This report describes the Renewable Energy RD&D Roadmap process and the detailed roadmaps developed by PIER Renewables.

- Chapter 2 outlines the main renewable energy policies in California that PIER Renewables supports.
- Chapter 3 provides the vision, platforms, and strategic objectives derived from the policy goals described in Chapter 2 and provides the framework for the Roadmap.
- Chapter 4 contains the detailed Roadmaps for 11 renewable energy resources and technology areas. These Roadmaps contain the RD&D milestones that PIER Renewables and stakeholders consider important to support the state in meeting key policy goals.
- Chapter 5 describes how PIER Renewables will use the Roadmap as an ongoing planning tool to define short-term research funding priorities.

CHAPTER 2: CALIFORNIA RENEWABLE ENERGY POLICY

Overview

The primary role of PIER Renewables is to help the state meet aggressive renewable energy policy goals by investing in high priority RD&D projects. The guiding principle of the Roadmap is to clearly link the Energy Commission's PIER RD&D in renewable energy to key state Renewable Energy goals. This chapter outlines the policy goals determined by PIER Renewables to be the most important for the state. This set of policy goals is fundamental to the Roadmap framework, and will guide PIER Renewables in its RD&D investments.

Figure 6 identifies the main policy documents reviewed in this effort.

Figure 6: Policy Documents Reviewed by PIER Renewables

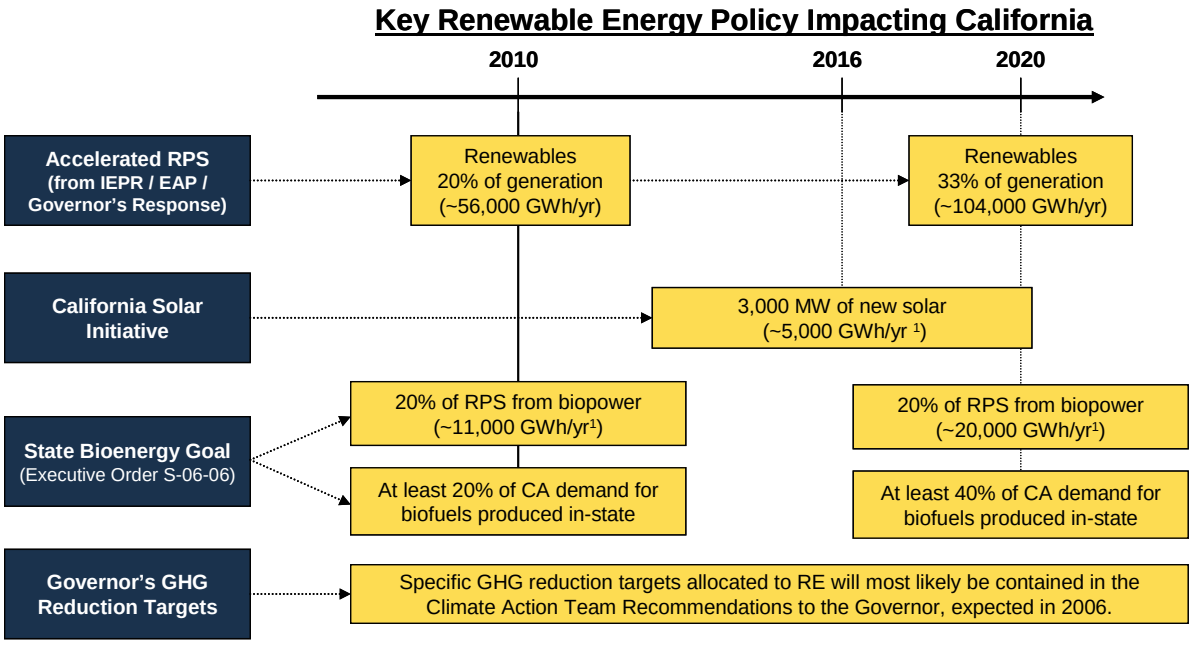
Key California Renewable Energy Policy Documents
• Integrated Energy Policy Reports (IEPR) (2003, 2004 update, 2005)
• Energy Action Plan (EAP) I and II (published 2003 and 2005 respectively)
• Governor's 2003 / 2004 IEPR response and Ten Point Plan
• California Solar Initiative (CPUC Proceeding R.06-03-004)
• State Bioenergy Goals (Governor's Executive Order S-06-06) and Bioenergy Action Plan
• Governor's GHG Reduction Targets (Governor's Executive Order S-3-05)
• U.S. 2005 Energy Policy Act
• Western Governor's Association (Charter, 2005 Annual Report, 2003 Policy Roadmap)

Key state renewable energy policy goals identified include the:

- 20 percent Renewables Portfolio Standard (RPS) for 2010.
- 33 percent Renewables goal for 2020.
- California Solar Initiative.
- State Bioenergy Goals.

In addition, PIER Renewables identified Governor Schwarzenegger's greenhouse gas (GHG) reduction targets as set in Assembly Bill 32 (shown in Figure 7) as a potentially important policy for renewables in the future. In Figure 7, the key state renewable energy policies that govern PIER Renewables investments are shown on a timeline. For reference, the figure also contains estimates of the results of each policy in terms of gigawatt-hours (GWh) produced annually by the year specified.[2]

Figure 7: Key Renewable Energy Policies Impacting California



1. Assumed average capacity factors are 20% for solar and 90% for biopower.
Note: The roadmap also considered detailed policy guidance as stated in the IEPR.

Policy Update - Assembly Bill 32 (Global Warming Solutions Act Of 2006) and Executive Order S-3-05

On September 27, 2006, three months after this report was written, the Governor of California signed into law Assembly Bill 32 (Nunez), Chapter 488, Statutes of 2006. The bill calls for a reduction in greenhouse gas (GHG) emissions to 1990 levels by 2020.

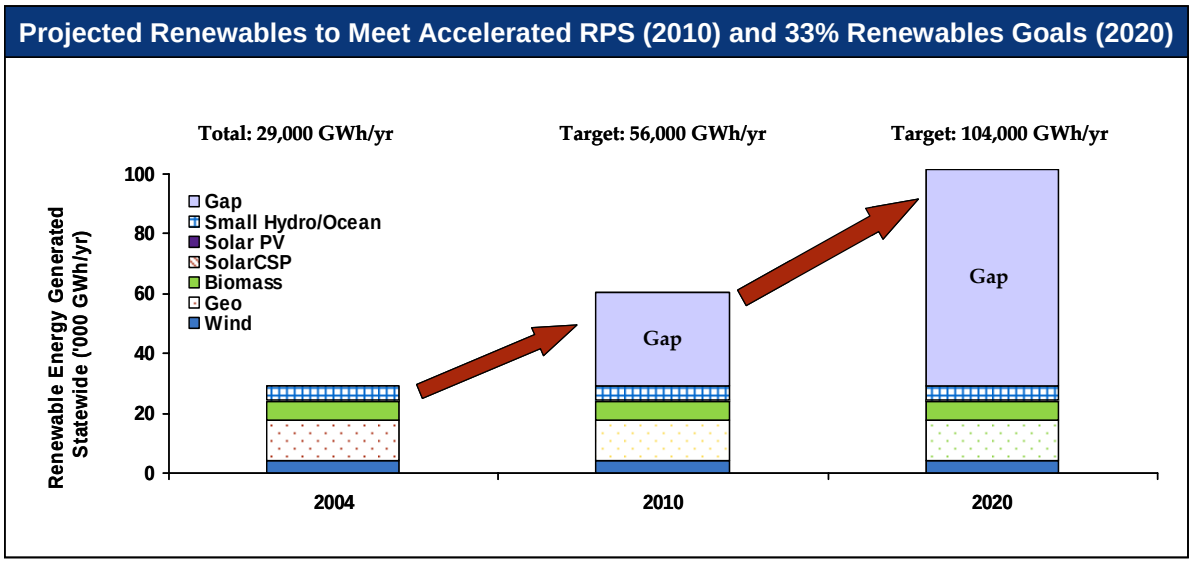
Before this official legislation, the Governor had set the following GHG reduction targets: by 2010, reduce GHG emissions to 2000 levels; by 2020, reduce GHG emissions to 1990 levels; by 2050, reduce GHG emissions to 80 percent below 1990 levels (Executive Order S-3-05).

Although no direction has been given on exactly how these targets shall be achieved, renewable generation is expected to play a critical role in reducing GHG emissions.

RPS and 33 percent Renewables Goals

The RPS (2010) and 33 percent Renewables Goals (2020) will have a tremendous impact on the amount of renewable generation in California. PIER Renewables helps industry and policy makers in the state achieve these goals by performing and supporting high priority RD&D to close the gap between the current renewable energy baseline in the state and the targeted amounts for 2010 and 2020. Figure 8 depicts the gap between baseline and RPS target needs.

Figure 8: Renewables to Meet 20 percent Accelerated RPS (2010) and 33 percent Renewables Goal (2020) (GWh)



Sources: 2004 data from California Energy Commission Electricity Report, includes all renewables in the state, including generation by non-IOUs; 2010 and 2020 data are PIER Renewables scenario projections.

California Solar Initiative

The California Solar Initiative (CSI) (CPUC Proceeding R.06-03-004) stimulates the development of 3,000 MW of new solar installations in the state by 2017. Solar installations that qualify for the CSI include both solar photovoltaic (PV) and solar thermal electric technologies, with a clear emphasis on distributed generation. With relatively low capacity factors for solar PV systems, CSI contributions toward RPS targets are not anticipated to be very large. However, developing a sustainable technology base of cost-effective distributed technology supports these objectives of promoting a sustainable solar industry, potentially lowering costs, fostering growth in this California-based sector, and reducing greenhouse gas emissions.

State Bioenergy Goals

The Governor's Executive Order S-06-06 and the Bioenergy Action Plan outline state bioenergy goals. These documents cover both biopower, often referred to as biomass power, and biofuels, such as ethanol and biodiesel. This Executive Order sets a goal that 20 percent of the renewable energy used for generating electricity and meeting the state's renewable energy goals in 2010 and 2020 should come from biopower.

Similarly, the Executive Order sets goals for increasing reliance on in-state production of biofuels. Currently, California imports more than 95 percent of the biofuels used in-state[3]. The Executive Order states that California should produce at least 20 percent of the biofuels consumed in the state by 2010 and 40 percent by 2020.

The agencies of the Bioenergy Interagency Working Group are committed to seeing these goals are met. The Bioenergy Action Plan, developed by the Working Group, provides the specific actions and timelines that the agencies have agreed to take to implement the Executive Order.[4]

Additional Policies that May Influence Roadmap

During the development of the Roadmap, PIER Renewables paid close attention to the strategic suggestions established by the Integrated Energy Policy Reports (IEPR) developed by the Energy Commission in 2003, 2004 (update only), and 2005. The IEPR documents provide guidance on implementation measures to meet RPS targets. In some instances the IEPR provides clear reference to RD&D. For example:

> *"The state needs to pursue additional research and development activities at the Energy Commission and the California Independent System Operator to address the impacts of integrating intermittent renewables, such as wind, into the state's transmission system."*

In other instances, the IEPR provides a desired outcome that implies a research agenda. For example:

> *"Expand the use of biodiesel fuels."*

The IEPR documents were carefully reviewed to determine which renewables RD&D would support the desired outcomes as described in the IEPR.

In addition to the three main California renewable energy policy goals described above, additional policies in the future will influence the Roadmap. For example, the Governor's GHG reduction targets may contain targets for renewables. As of June 2006, the Governor has not released these GHG reduction targets for renewables.

Since the Roadmap is a living document, PIER Renewables can integrate new renewables goals from the Governor's GHG reduction targets as they emerge.

The Roadmap is designed as a living document to incorporate policy modifications as well as additions. Existing renewable energy policies in California will evolve with the market and technology and new policies will be developed. In addition, regional and federal policies may influence the Roadmap in the future. The flexibility of the Roadmap as a planning tool for PIER to incorporate policy changes will be discussed briefly in Chapter 5.

CHAPTER 3: ROADMAP KEY ELEMENTS

Introduction

The key state renewables energy policy goals described in Chapter 2 form the foundation of this Roadmap. The framework of the Roadmap is composed of the vision, platforms, strategic objectives, and milestones. This chapter describes each of these elements and then pulls together all of the elements discussed so far into a graphical framework that will be used throughout the rest of the document.

Vision

The vision statement briefly describes the target that PIER Renewables hopes to help the state achieve. The vision developed by PIER Renewables for the Roadmap is:

> "*Renewable energy resources will provide at least 33 percent of the electricity by 2020 for the California energy system, providing consumers and energy providers with affordable, reliable, secure, and diverse clean energy services.*"

The vision of PIER Renewables is closely tied to the 33 percent renewable energy goal (2020). PIER Renewables considers that this vision includes both the CSI, which calls for approximately 3,000 MW of solar by 2016, and the state bioenergy goals, which call for 20 percent of the 33 percent renewable energy goal to be provided with biopower.

The Roadmap addresses biofuels and natural gas issues only in areas where they overlap with renewable energy as it pertains to electricity generation.

Platforms

The platforms establish strategic areas of focus for investment and management attention and indicate areas where PIER Renewables hopes to make an impact. PIER Renewables developed four platforms to help organize and structure research activities. PIER Renewables will prioritize investments from the potential RD&D activities on the Roadmap, as described at a high level in Chapter 5.

Platform 1: Production Resources and Technology

This platform contains RD&D activities that deal with renewable resources and generating technologies. In addition, this platform includes RD&D activities that deal with the production of transportation fuels using renewable resources, such as biomass.

RD&D activities in this platform have traditionally formed the majority of investments made by PIER Renewables, concentrating on improving performance and reducing cost of renewable energy generating technologies and developing renewable energy resources. PIER Renewables now also includes RD&D activities aimed at developing biofuel production since biopower and biofuels overlap with regard to some biomass resources and technologies. As advancing science and technology is one of the PIER goals, this platform will continue to be important for PIER Renewables.

Platform 2: Grid Integration

This platform contains RD&D activities for effectively connecting renewable generation to the electrical transmission and distribution system.

PIER Renewables has funded some RD&D activities in this platform in the past. The RPS and other key state renewable energy policy goals will continue to require effective integration of renewable energy generating technologies into the existing electrical system, and significant RD&D investments will be required from this platform. The state will need to plan for effective integration of renewable energy generating technologies into the electrical system, including RD&D activities to develop technologies for storing, shaping, monitoring, and forecasting renewables.

Platform 3: End Use

This platform contains RD&D activities that encourage end-user adoption of distributed renewables by addressing technology and market issues.

Like Platform 2, PIER Renewables has funded RD&D activities in this platform in the past, and it will continue to be important given current state policy goals. For example, meeting CSI goals will require improved performance, ease of use, and economics of distributed generation (DG) PV systems. This platform includes other DG technologies located near the end user such as DG wind, small biogas systems, and even small geothermal applications. RD&D activities that develop end-use technologies and interconnection, such as improved metering, monitoring, storage and electricity conversion are critical for the growing PV market in California. PIER Renewables will also target projects such as building integrated PV (BIPV) technologies that incorporate these technologies more seamlessly into buildings.

Platform 4: Market Transformation

This platform contains RD&D activities that encourage renewable adoption by addressing issues that hinder market growth including inadequate policy, outdated regulation, and lack of incentive structure as well as market acceptance of technology.

Meeting California's renewable energy goals will require the development of policies, regulations, and incentives that support sustained renewable energy market growth. In addition, market acceptance of renewables will depend on confronting misconceptions and resistance to system siting. RD&D activities in this platform support the development of informed and solid formation of policy, regulation, and incentives, especially when tailored to the needs of policy makers to understand the issues, market hurdles, and options.

Strategic Objectives

Within each platform, PIER Renewables identified strategic objectives that will help establish priorities in RD&D funding. Figure 9 provides the strategic objective for each platform.

Figure 9: Platforms and Strategic Objectives

Platform	Strategic Objective
Production Resources and Technology	Support commercialization of renewable energy options.
Grid Integration	Enable renewable energy grid integration.
End Use	Support end-user adoption of renewable energy.
Market Transformation	Support appropriate market mechanisms and policies that enable sustainable renewable energy growth.

Milestones

Milestones are a series of measurable goals, each with a target date that together will help accomplish the strategic objectives. The milestones break the strategic objectives down into a series of "bite-size" goals. They also mark an endpoint to achieving a goal. Milestones should not be considered as one research activity, but instead are often the result of multiple activities, projects, investments, and players.

Figure 10 provides examples of milestones and non-milestones.

Figure 10: Example of Milestones

This is a Milestone…	This is not a Milestone…
• Transmission plan to access key solar CSP resources is in place • Widespread use of transformerless design for PV inverters	• Assemble working group to determine CSP transmission needs in state • Test operating conditions and safety of transformerless PV inverters

RD&D milestones were developed for 11 resource/technology areas and for an additional category called "Shared Renewables Issues", which captures RD&D concerns that are shared by more than one resource/technology area. The RD&D milestones were developed to identify the critical areas for RD&D required to help support the successful implementation of California's key renewable energy policy goals. As part of the process, PIER Renewables looked at specific barriers to each resource/technology area as one way to determine what RD&D is required.

The milestones were created over a series of months using the inputs and processes described previously in this report, including:

- Review of key policy documents (Figure 6).
- Input from RD&D organizations and key stakeholder organizations (see list in Appendix).
- Input from PIER Renewables area leads and staff.
- Input from public workshop with key stakeholders (>30 external and >20 internal to the Commission).

Because milestones mark the accomplishment of specific goals, in many cases they will require various projects and multiple years of investment. The detailed roadmaps in the following chapter only show the milestone goals and do not go into detail on the projects and investments required to achieve the milestones.

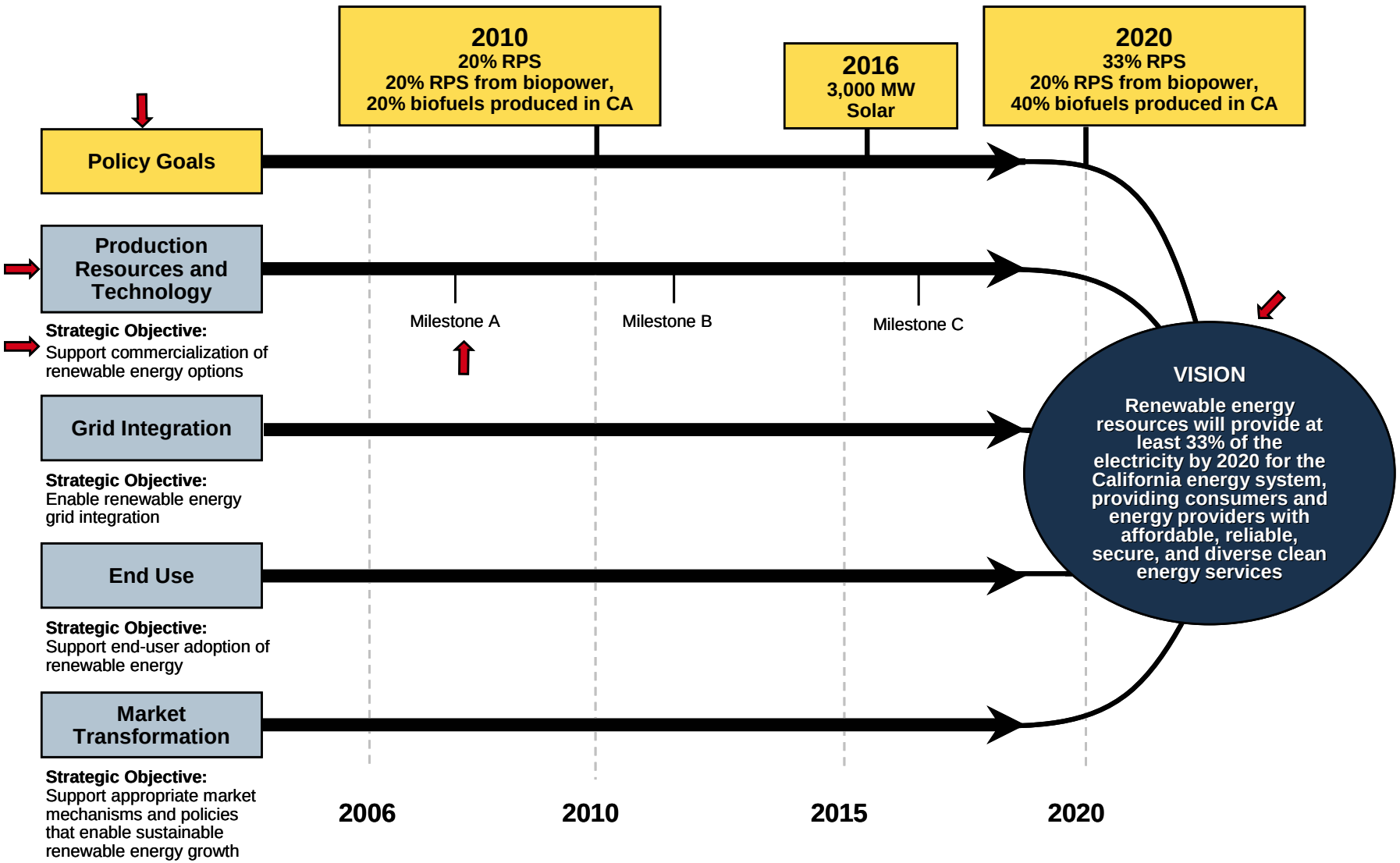
This level of detail will be developed once PIER prioritizes areas of investment and develops a project portfolio.

Actual milestones for each renewable resource/technology area are presented by resources/technology area in Chapter 4.

Roadmap Pulled Together

Figure 11 on the following page is a graphical representation of the integration of the five elements of the Roadmap: policy goals, vision, platforms, strategic objectives, and milestones.

Figure 11: Renewable Energy RD&D Roadmap



CHAPTER 4: DETAILED ROADMAPS BY RESOURCE/TECHNOLOGY

Introduction

The detailed roadmaps identify key areas where investment in RD&D can help California meet its key renewable energy policy goals. PIER Renewables developed detailed roadmaps for the renewable energy resource/technology areas and natural gas. Figure 12 shows the list of the renewable areas for which detailed roadmaps were prepared.

Figure 12: List of Detailed Roadmaps

Detailed Roadmaps
• Shared Renewable Issues • Utility Scale Wind • Geothermal • Biopower • Biofuels • Solar CSP • Solar PV • Small Hydro • Ocean/Wave/Tidal • DG Wind • Natural Gas Replacement

PIER initially identified five renewable resource/technology areas for which it has made or contemplated making investments: wind, geothermal, bioenergy, solar, and water. In some cases it made sense to consider more refined categories to more accurately capture the very different needs, timelines, and potential contributions of the resources or technologies considered. For this reason wind was divided into utility-scale wind and DG wind, solar was divided into solar photovoltaic (PV) and concentrating solar power (CSP), bioenergy was divided into biopower and biofuels, and water was divided into small hydro and ocean/wave/tidal. In addition, PIER realized that some RD&D concerns overlap resources/technology boundaries and therefore developed a roadmap for shared renewables issues. Finally, as discussed in Section 1 and shown in Figure 1 of this report, PIER Renewables is incorporating issues that overlap with natural gas replacement (for example, solar thermal hot

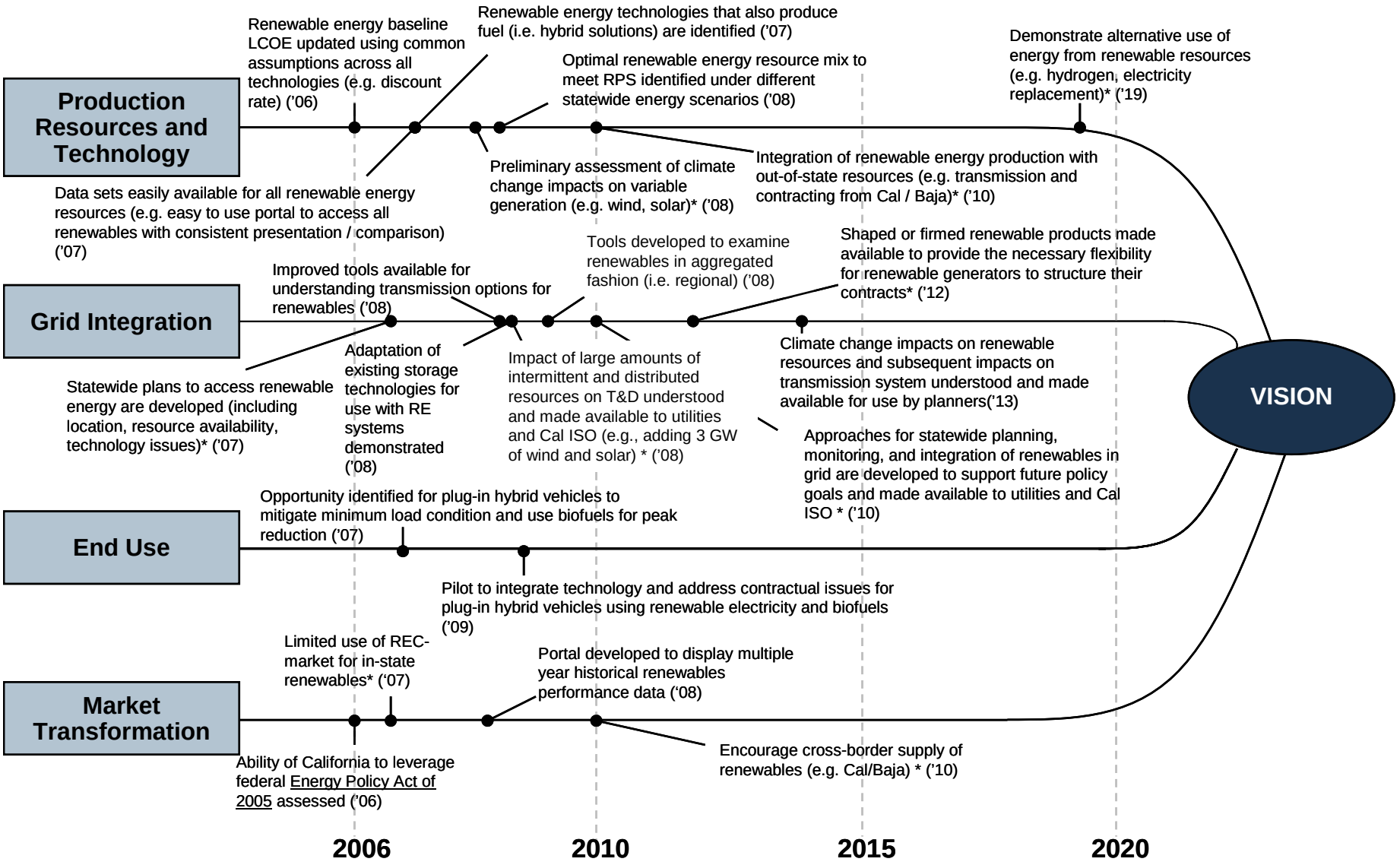
water heating and biogas production), and for this reason a natural gas displacement roadmap was added.

The Detailed Roadmaps are shown in the following pages.

Note: On the following Detailed Roadmaps any milestone marked with "*" indicates that the milestone is in alignment with strategic direction provided in one of the Integrated Energy Policy Reports developed by the Energy Commission (2004, 2005 update or 2005). The milestones articulate RD&D needs resulting from the strategic direction provided in the IEPR and do not correlate verbally with what is in the IEPRs.

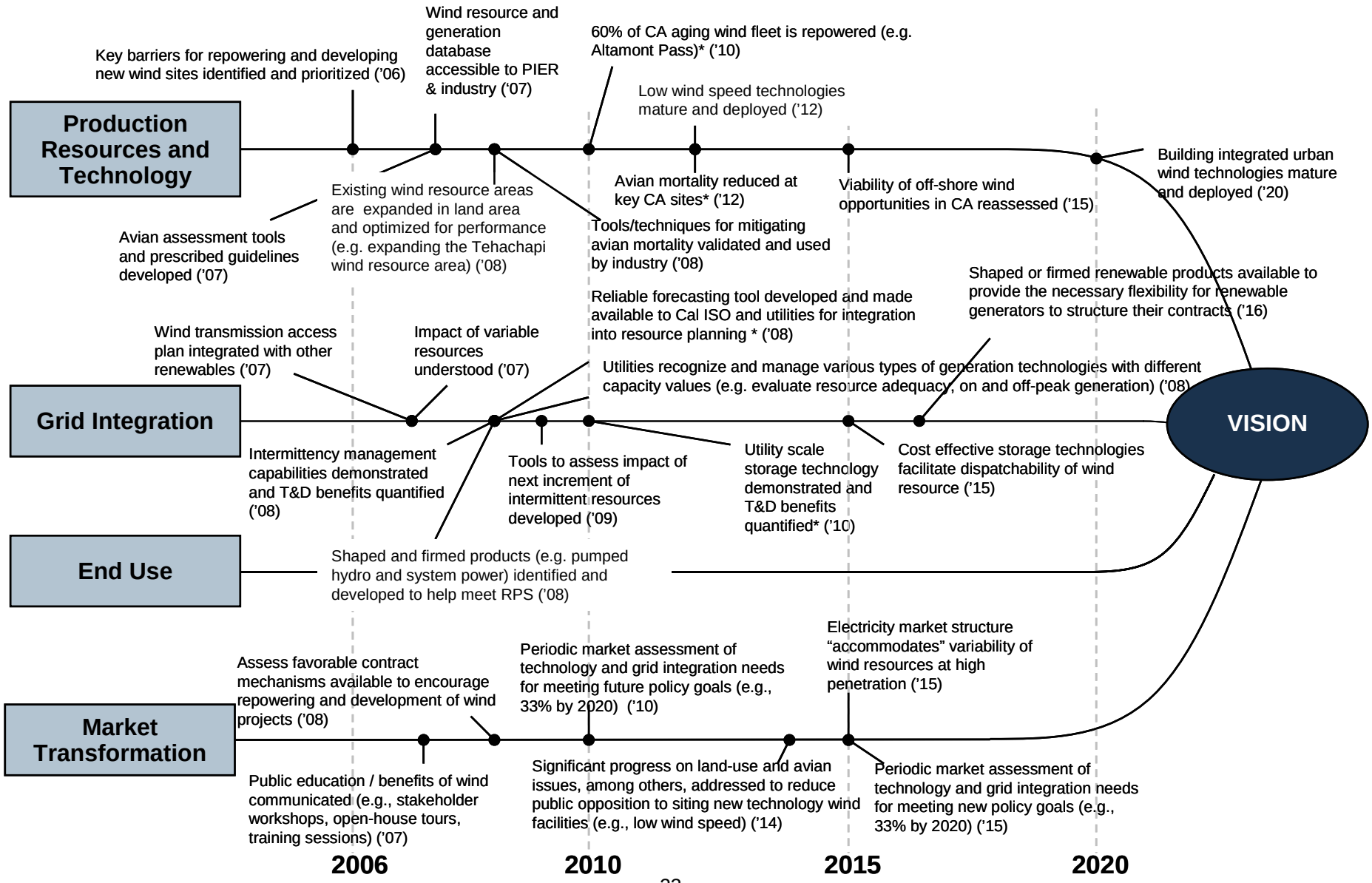
Shared Renewables Issues

Figure 13: Shared Renewables Detailed Roadmap



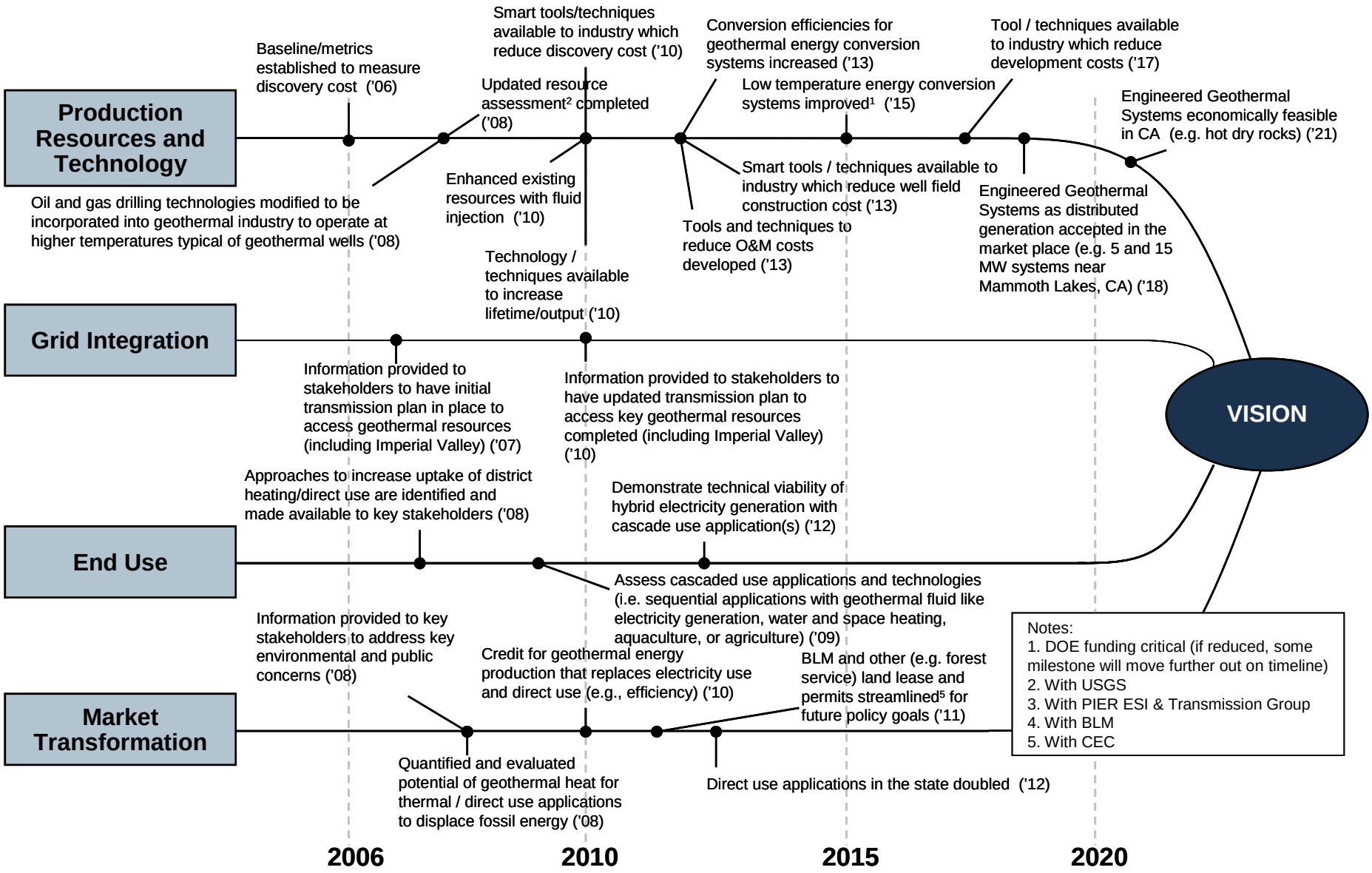
Utility Wind

Figure 14: Utility Wind Detailed Roadmap



Geothermal

Figure 15: Geothermal Detailed Roadmap



Biopower

Figure 16: Biopower Detailed Roadmap (1 of 2)

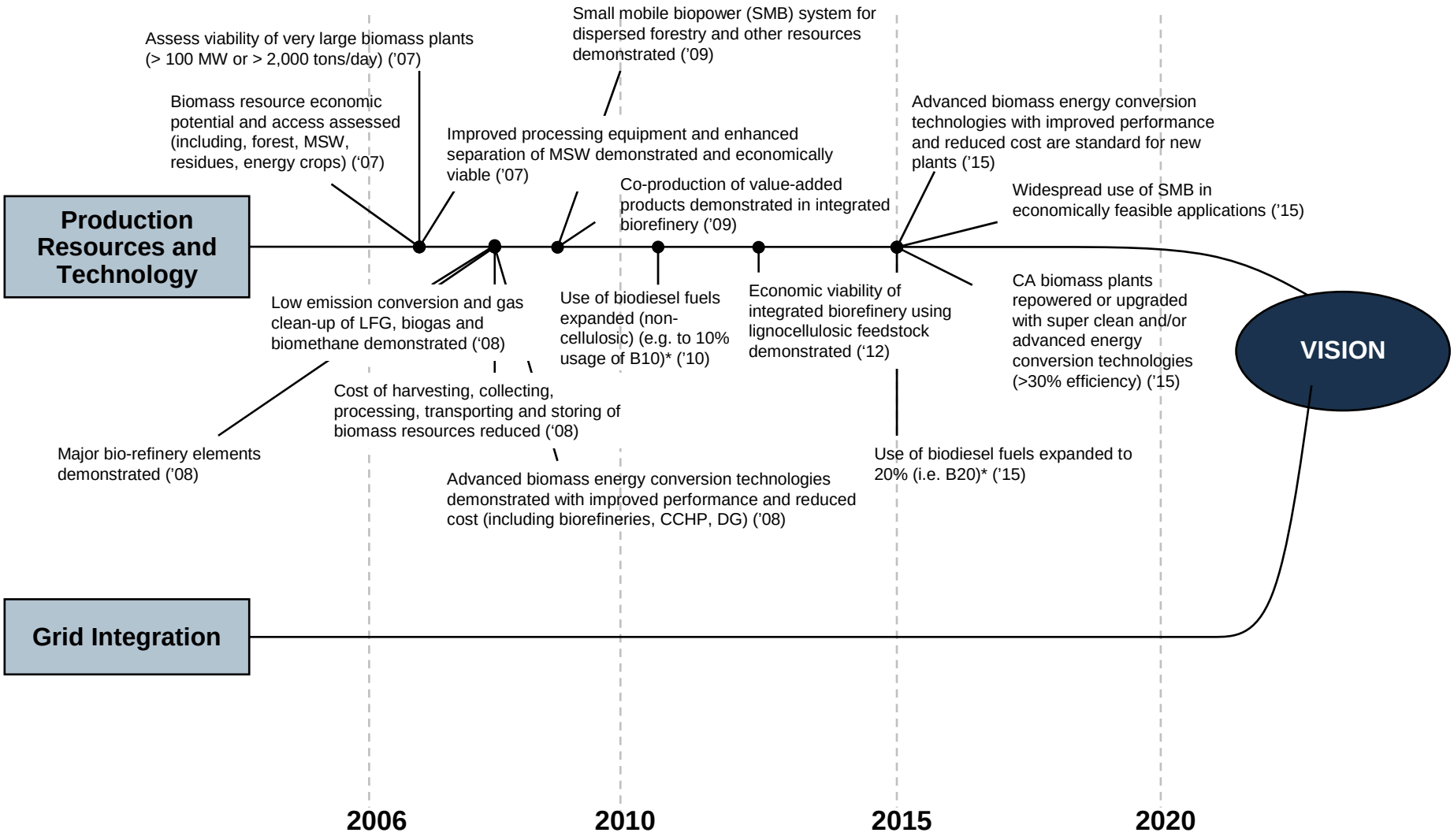
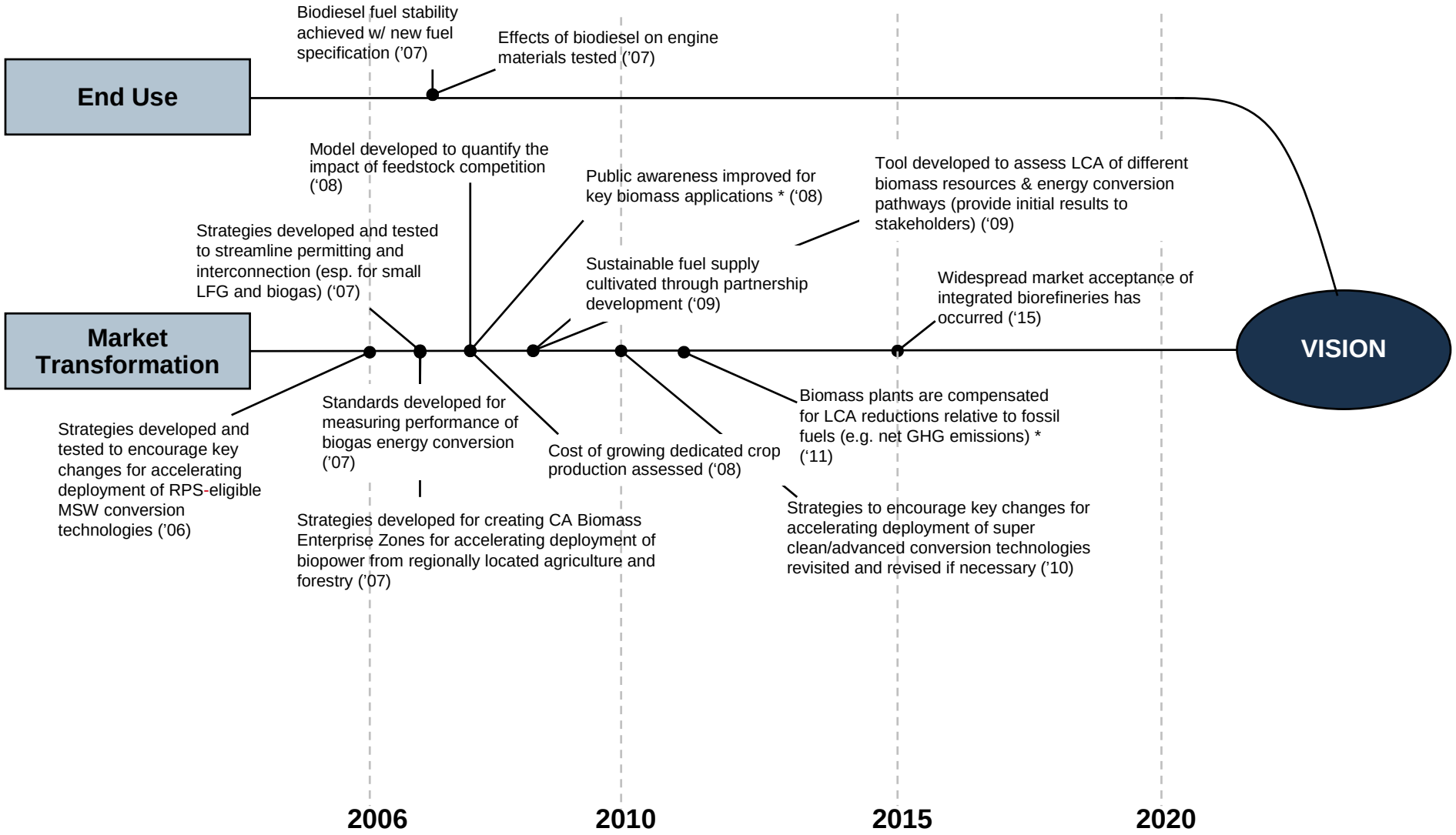
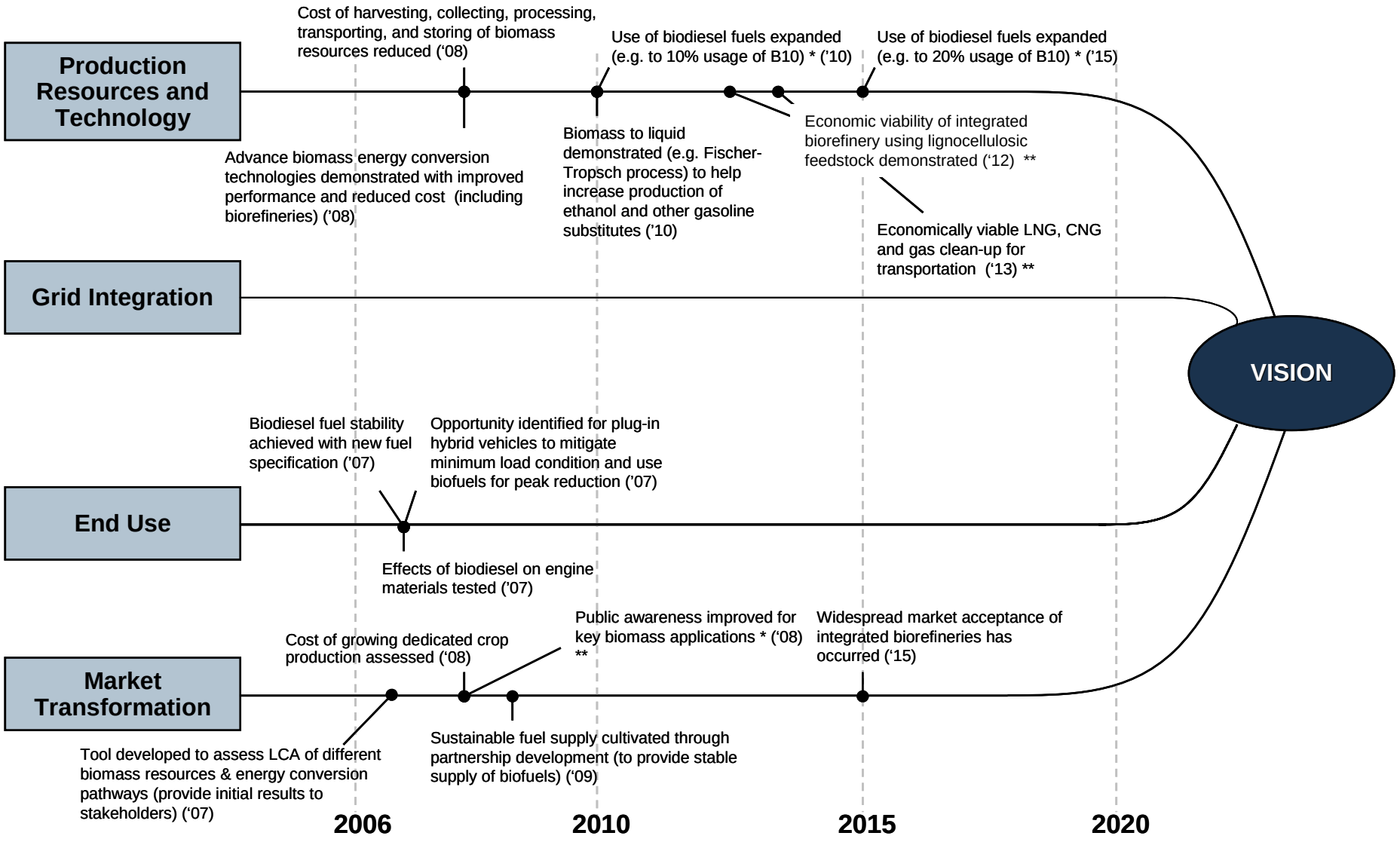


Figure 17: Biopower Detailed Roadmap (2 of 2)



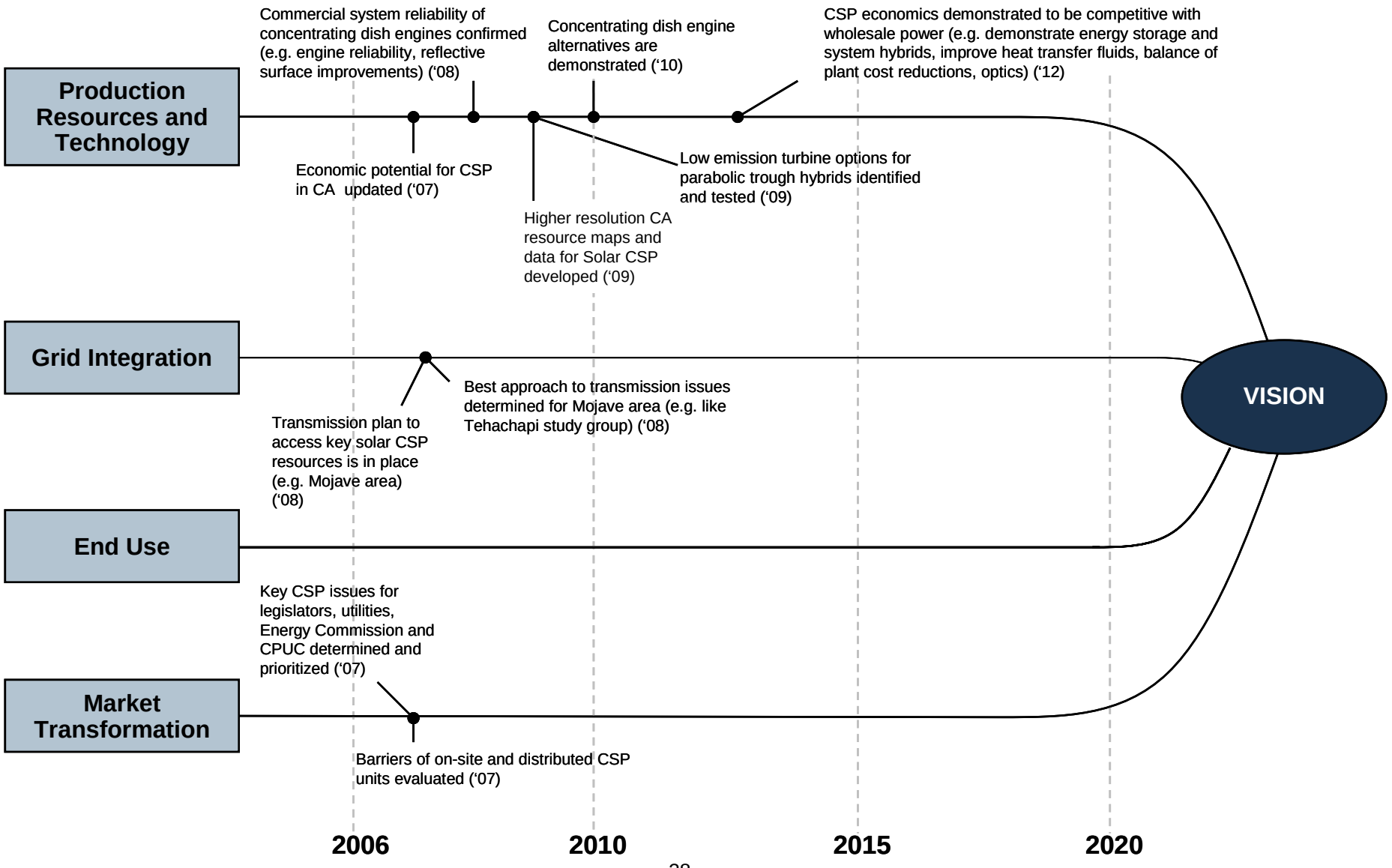
Biofuels

Figure 18: Biofuels Detailed Roadmap



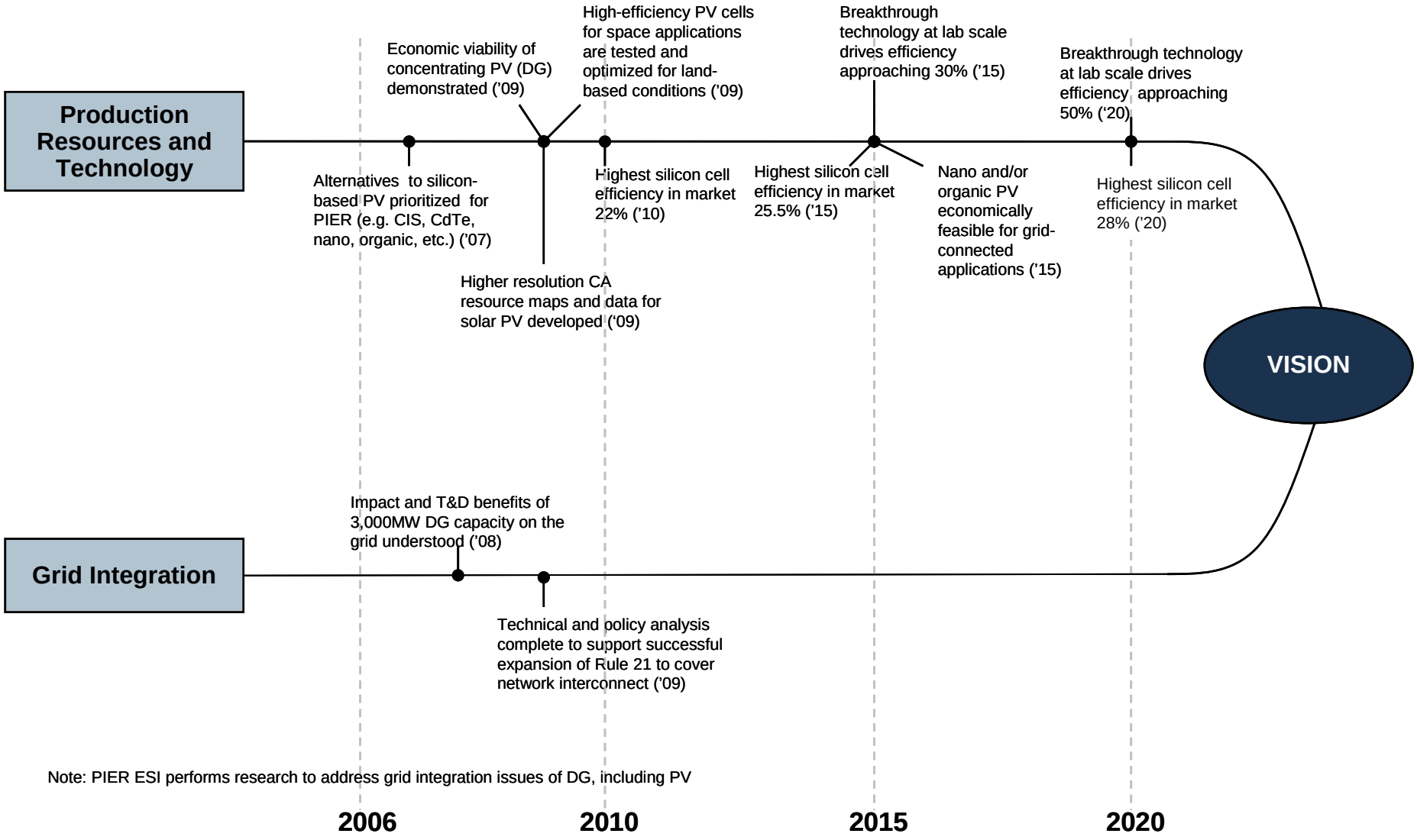
Solar CSP

Figure 19: Solar CSP Detailed Roadmap



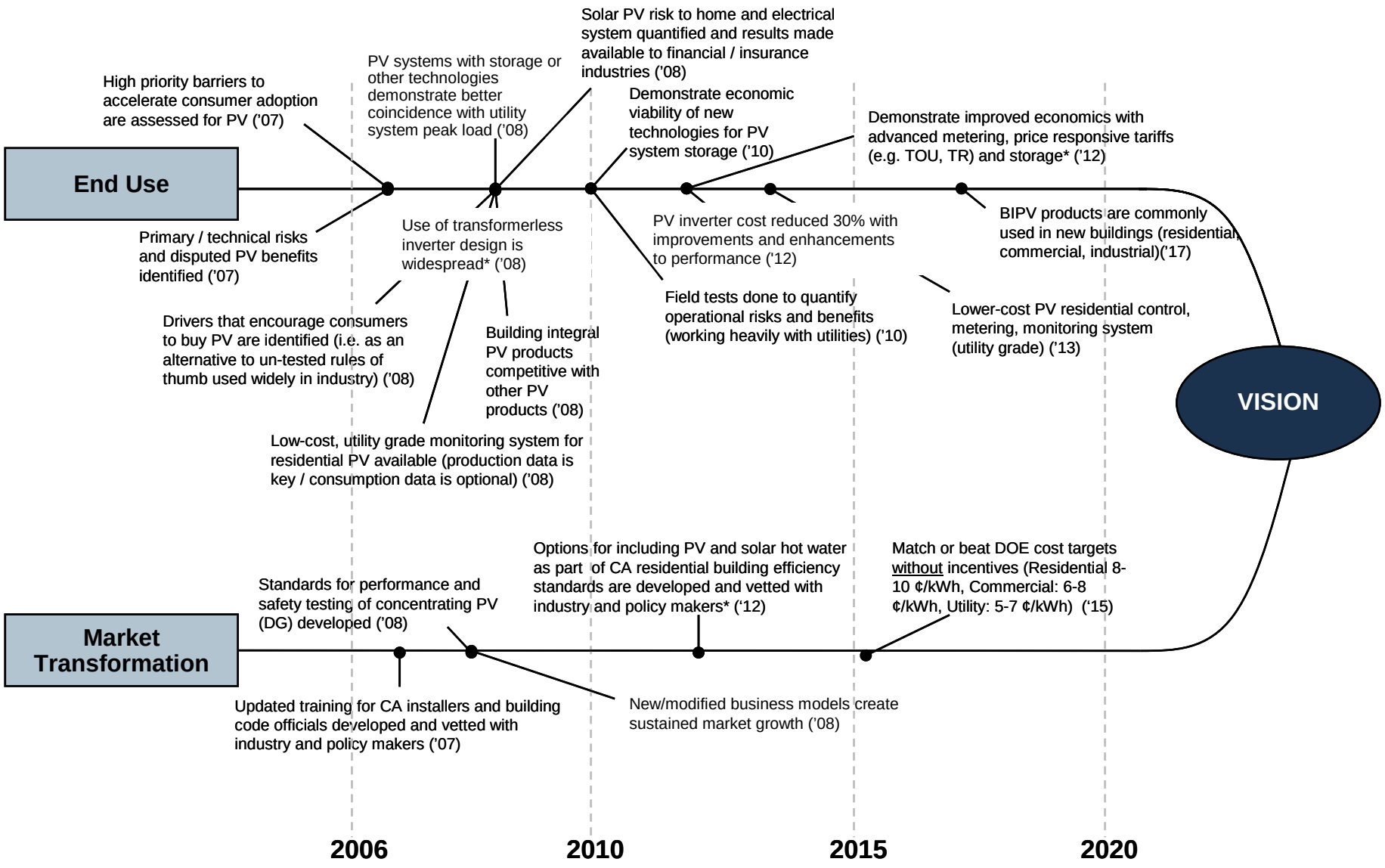
Solar PV

Figure 20: Solar PV Detailed Roadmap (1 of 2)



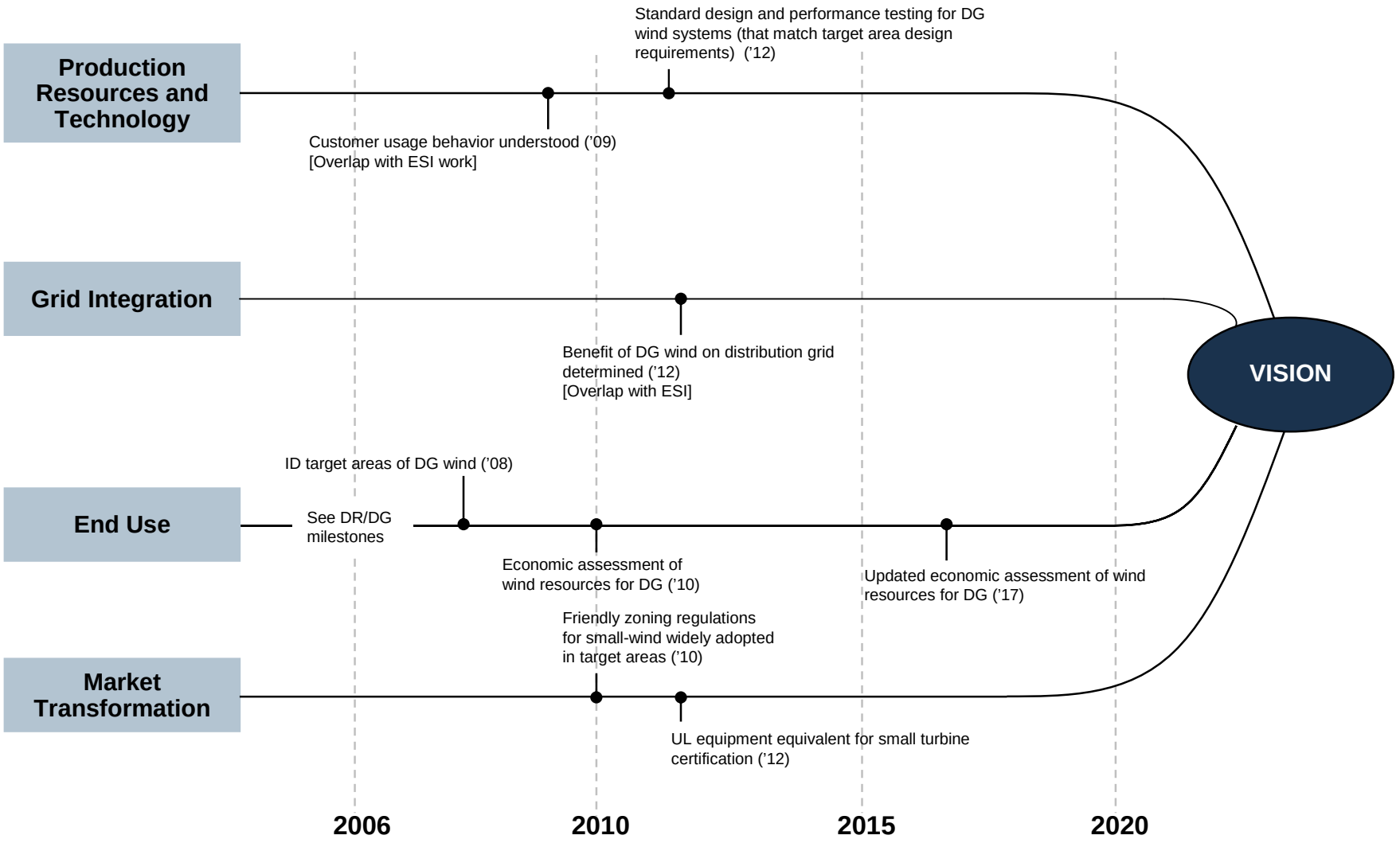
Note: PIER ESI performs research to address grid integration issues of DG, including PV

Figure 21: Solar PV Detailed Roadmap (2 of 2)



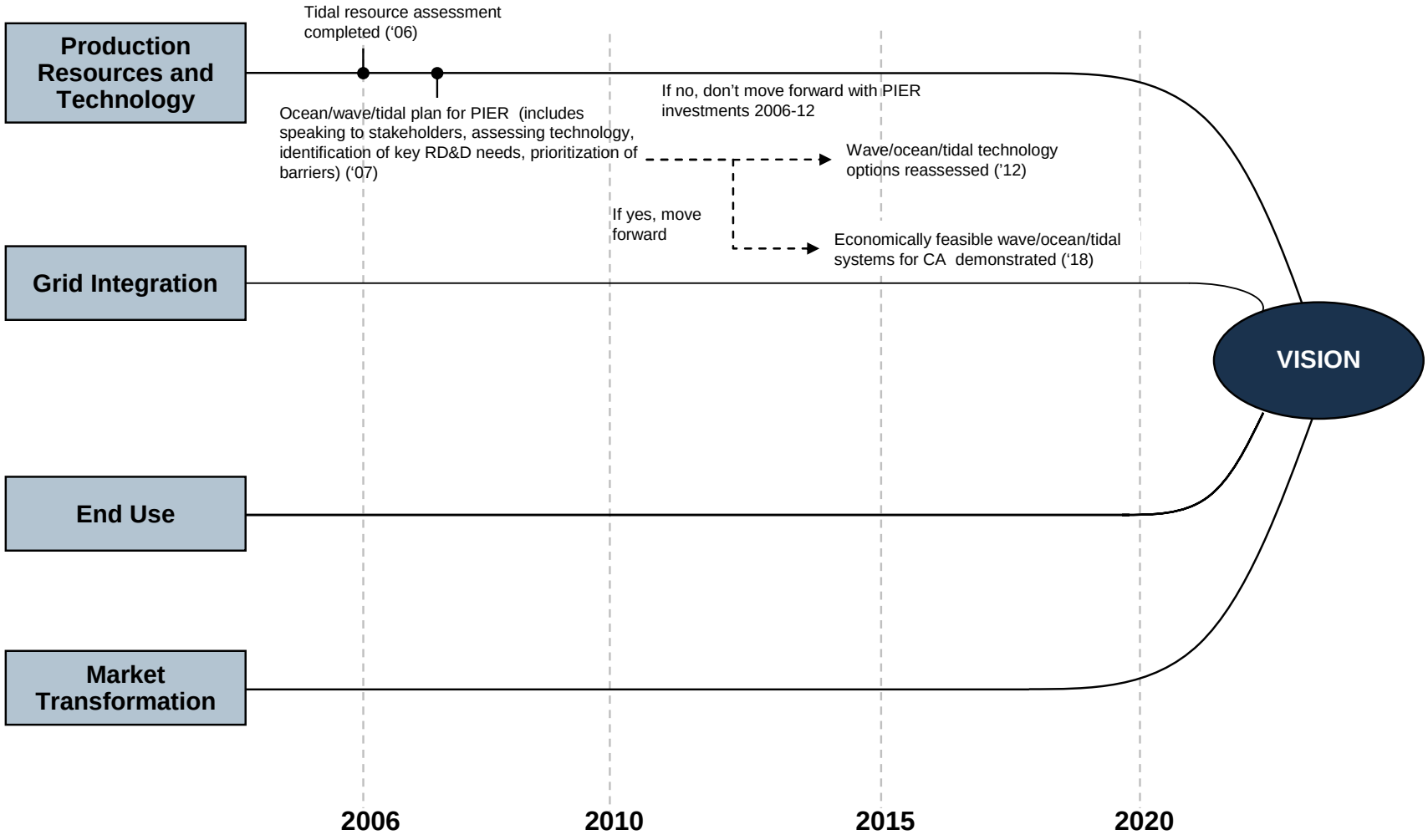
DG Wind

Figure 22: DG Wind Detailed Roadmap



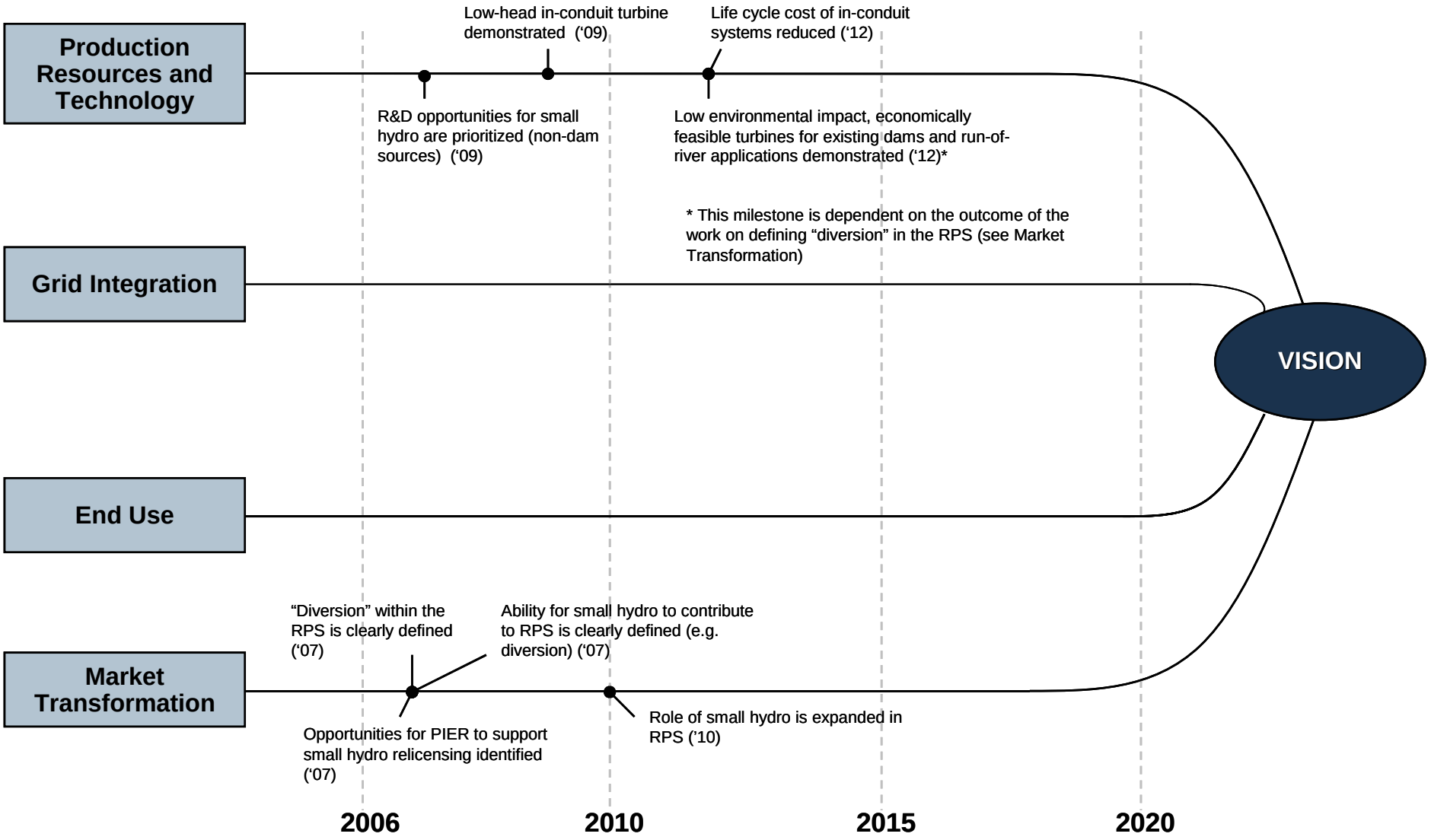
Ocean/Wave/Tidal

Figure 23: Ocean/Wave/Tidal Detailed Roadmap



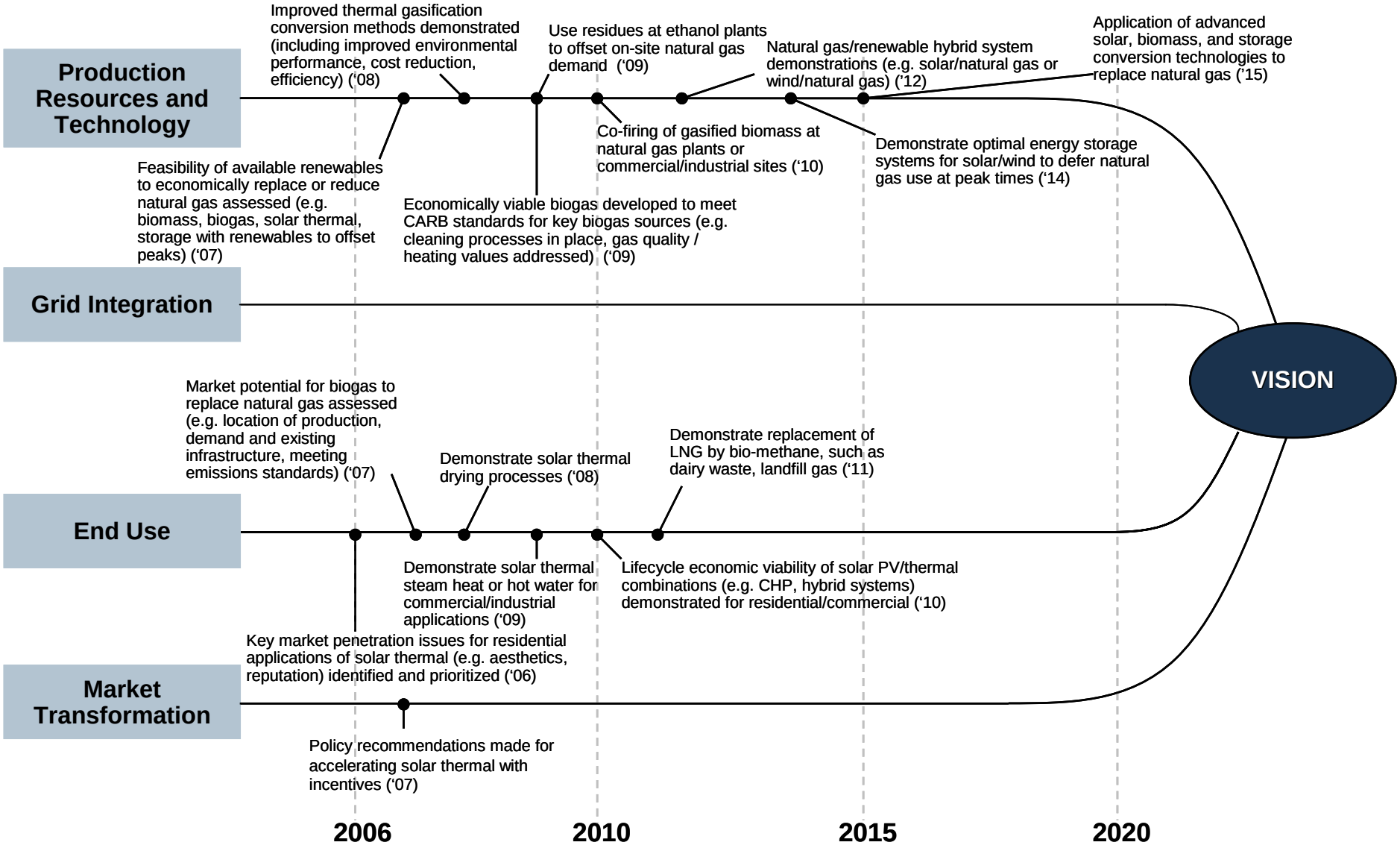
Small Hydro

Figure 24: Small Hydro Detailed Roadmap



Natural Gas

Figure 25: Natural Gas Detailed Roadmap

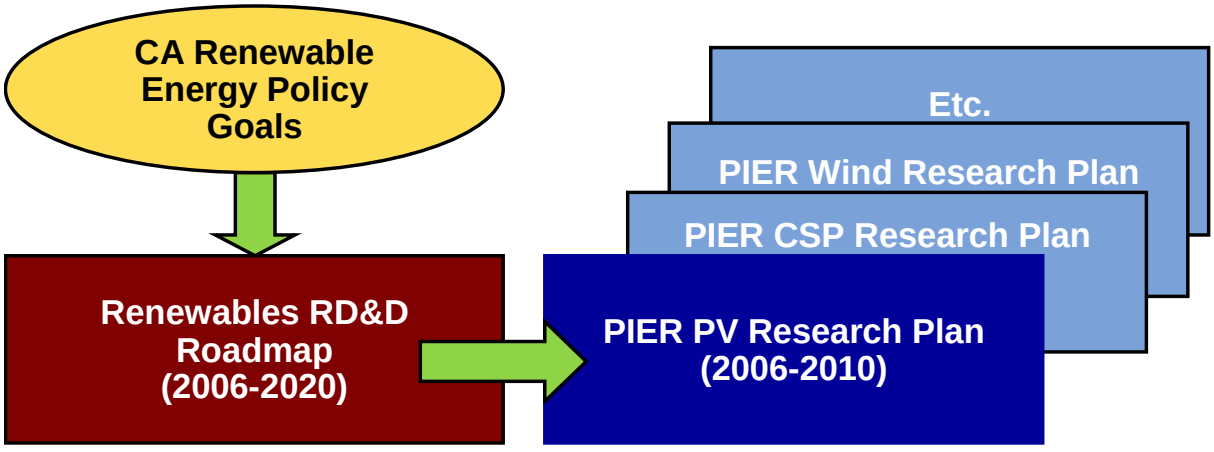


CHAPTER 5: RENEWABLES ROADMAP AS ONGOING PLANNING TOOL

While the Renewables Roadmap provides a comprehensive view of RD&D milestones needed for the state to meet its ambitious renewable energy policy goals, PIER Renewables has limited funds and, as a result, must develop research plans by technology/resource area to prioritize the RD&D milestones identified in the Roadmap. In general, PIER Renewable will concentrate on areas that can have the highest impact on meeting state policy goals and where there are research gaps due to lack of funding by other RD&D organizations. A steering committee, formed by key renewable energy decision makers across the Energy Commission, will guide the development of the research plans. Moreover, the research plans will rely on input from key stakeholders to prioritize RD&D needs, including government, utilities, industry companies, advocacy groups, and research organizations.

As illustrated by Figure 26, the Solar PV Research Plan will be the first of a series of research plans to be developed for each renewable energy resource/technology area identified in the Renewables Roadmap. Each research plan will define priority RD&D investments over the short term (2006-2010) for PIER that will help the state meet its aggressive policy goals. The Solar PV Research Plan will also serve as a model approach that PIER Renewables can use to prioritize research needs for the remaining resource/technology areas identified in the Renewables Roadmap.

Figure 26: Process to Develop Research Plans by Technology/Resource Area



To complement PIER investments, PIER Renewables will coordinate with RD&D efforts at a variety of institutions, both public and private, including the Federal government, other state governments, universities, companies, and even other groups within PIER and the Energy Commission.

As a living document, the Roadmap is expected to evolve over time to reflect changes in RD&D needs due to technology developments and shifts in state policy priorities. As it currently stands, the Roadmap is a solid starting point for PIER Renewables to prioritize RD&D needs and develop focused short- to medium-term research plans and project portfolios that will most effectively use its limited funding to help support successful implementation of key California state policy goals.

APPENDIX

List of Interviews

Technical Focus	Organization	Name
Wind	Electric Power Research Institute	McGowin, Chuck
	National Renewable Energy Laboratory	Thresher, Bob
Geothermal	Geothermal Energy Association	Gawell, Karl
	Oregon Institute of Technology	Lund, John
	Ormat	Schochet, Dan
Biomass	National Renewable Energy Laboratory	Pacheco, Michael
	U.S. Department of Energy	Grabowski, Paul
Solar CSP	APS Solar Partners	Hayden, Herb
	National Renewable Energy Laboratory	Mancini, Tom Mehos, Mark
Solar PV	Miasole	Pearce, David Wenzel, Martin
	SunPower	Mulligan, Bill
	U.S. Department of Energy	King, Richard
Ocean / Tidal	Electric Power Research Institute	Bedard, Roger
Natural Gas Replacement	Gas Turbine Institute	Bush, Vann
Cross-Technology	California Clean Energy Fund	Adler, Dan Bicker, Lisa
	California ISO	Hawkins, Dave
	California Public Utilities Commission	Ryan, Nancy (advisor to Commissioner Peevey)
	Pacific Gas & Electric Co.	La Flash, Hal Treleven, Kathleen
	Southern California Edison	Chacon, Jorge
	San Diego Gas & Electric/Sempra	Reed, Jeffery Sharma, Arun
	Sacramento Municipal Utility District	DeAngelis, Mike

List of Participants in April 6th Stakeholder Workshop

Name	Company	Title
Adler, Dan	CA Clean Energy Fund	Director, Technology and Policy Development
Alvarez, Manuel	Southern California Edison	Manager for Regulatory Affairs
Batham, Mike	Sacramento Municipal Utility District	Senior Project Manager
Berton, Fernando	CIWMB	
Bruton, Carol	Lawrence Livermore National Laboratory	Geothermal Program Leader
Cornelius, Craig	U.S. Department of Energy	Technology Manager
DeAngelis, Mike	Sacramento Municipal Utility District	Manager, AR&DGT
Eckard, Bob	Energy Commission	
Glass, Bob	Energy Commission	
Goncalves, Tony	Energy Commission	Supervisor
Gottlieb, Adam	Energy Commission	
Hawkins, Dave	Cal ISO	Manager, Special Projects
Hill, Roger	Sandia National Laboratories	Technical Director GPW
Hughes, Evan	Consultant	Biomass and Geothermal Consultant
Jenkins, Bryan	UC Davis	Professor & Director of the Biomass Collaborative
Kennedy, Mack	Lawrence Berkeley National Laboratory	
Kimbis, Tom	U.S. Department of Energy	Technology Acceptance Manager
LaFlash, Hal	Pacific Gas & Electric Co.	Director, Integrated Resource Planning
MacDougall, Ruth	Sacramento Municipal Utility District	Project Manager
Mancini, Thomas Dr.	Sandia National Laboratory	Director CSP Program Manager
Margolis, Robert	National Renewable Energy Laboratory	Senior Analyst
Mazanec, Frank	Waste Management	Managing Director
Morris, Gregory	Future Resources Associates	Principal
Peterson, Terry	Electric Power Research Institute	Solar Power Consultant

Peurach, Jack	PowerLight	VP Production Development
Pigott, Jack	Calpine Corp.	Director, Renewable Affairs
Ross, JP	Vote Solar	Director of Programs
Rotman, Doug	Lawrence Livermore National Laboratory	Program Leader
Sharma, Arun	Sempra	Technical Strategy Manager
Shears, John	CEERT	Visiting Research Fellow
Summers, Matt	California Dept. of Food and Agriculture	
Swanson, Richard Dr.	SunPower	President and CTO
van Dam, Case	UC Davis	Professor & Director of the Wind Collaborative (CWEC)
White, Chuck	Waste Management	Government Affairs
Wickizer, Doug	California Dept. of Forestry & Fire Protection	Chief, Environmental Protection and Regulations
Williams, Rob	UC Davis	Research Engineer
Allen, Jennifer	Energy Commission PIER	
Beyer, John	Energy Commission PIER	
Glassley, Bill	Energy Commission PIER	Technical Manager - Geothermal
Gutierrez, Pablo	Energy Commission PIER	
Kane, Mike	Energy Commission PIER	
Kibrya, Golam	Energy Commission PIER	Solar Team Lead
Koyama, Ken	Energy Commission PIER	Supervisor PIER Renewables
Mohammed, Hassan	Energy Commission PIER	Mechanical Engineer
Sethi, Prab	Energy Commission PIER	Project Manager
Sison-Lebrilla, Elaine	Energy Commission PIER	Mgr. Generation Research
Spaulding, Pete	Energy Commission PIER	Environmental Specialist II
Wiggett, Gail	Energy Commission PIER	Associate Geologist
Tiangco, Valentino	Energy Commission PIER	Biomass Team Lead
Yen Nakafuji, Dora	Energy Commission PIER	Wind Team Lead
Zhang, Jessica	Energy Commission PIER	

Endnotes:

[1] 2005 Annual Project Updates for the Public Interest Energy Research Program (PIER): http://www.energy.ca.gov/2006publications/CEC-500-2006-037/CEC-500-2006-037-SF.PDF

[2] The use of gigawatt-hour estimate of policy impact provides a common quantifier to allow easy comparison between policies.

[3] Navigant Consulting, Inc., March 2006, Recommendations for a Bioenergy Action Plan for California, Prepared for the Bioenergy Interagency Working Group, Sacramento, CA, Publication number CEC-700-2006-003-D, pg 10.

[4] Bioenergy Action Plan for California: http://www.energy.ca.gov/2006publications/CEC-600-2006-010/CEC-600-2006-010.PDF